Solving Design Problems in Electrical Circuitry

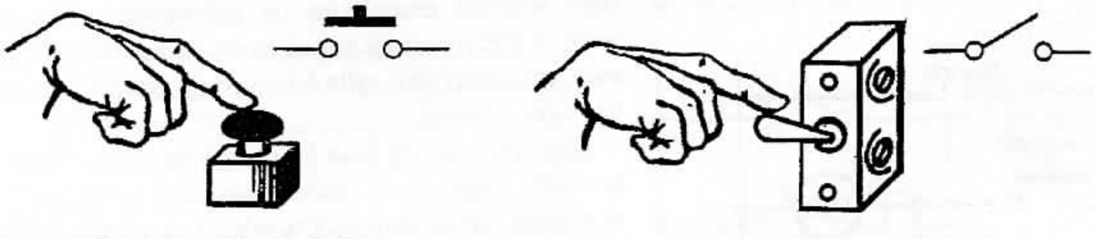
Most circuits in this book show standard fluid power movements controlled with more or less standard electrical circuits. In this chapter we will show examples of special circuit problems which may be encountered by a designer when he designs a circuit for a special application.

PROBLEMS ASSOCIATED WITH THE STARTING SIGNAL

All electrically controlled fluid power machines must be started every cycle with some kind of electric signal. This may come from an operator, from the output of another machine, or from a programmer such as a tape or card reader or from a programmable controller. But no matter where the signal may come from, it will be one of two kinds: (1), momentary, as from a pushbutton: (2), maintained, as from a toggle switch or rotary selector switch. Several distinct problems must be considered in dealing with such starting signals:

(1). A momentary signal of short duration, as from a pushbutton, must sometimes be converted into a maintained signal if it is used to energize (and hold) a spring return or spring centered valve. Design Problem No. 1 on the next page shows how this can be done with a holding relay.

(2). A maintained signal, as from a toggle switch, must be interrupted after it has done its work so it cannot interfere with normal progress in the cycle. The circuit must be designed with delay relays, timers, relay or switch contacts so the circuit can be broken ready for the next cycle.



Momentary Signal from Electric Pushbutton　　Maintained Signal from a Toggle Switch

FIGURE 6-1. Starting signals will be either momentary or maintained.

DESIGN PROBLEM No. 1

How to convert the momentary signal from a pushbutton into a maintained signal.

When operating a 4-way valve with spring return or spring centered spool, the spool will not remain in shifted position when the pushbutton is released. To keep the spool shifted, current must be kept on the valve coil by using a holding relay.

For operation of compressed air cylinders, only 2-position valves, either single solenoid with spring return or double solenoid no-spring models are normally used. Three-position air valves are seldom used because an air cylinder is unstable when stopped in mid-stroke.

Double solenoid, no-spring models adapt easily to pushbutton control because they will stay in shifted position when the pushbutton is released. However, single solenoid spring return models are more resistant against spool drift due to high "g" acceleration (when mounted on moving machines), by excessively high air flow across the spool, or by machine vibration. Their spools are positively retained at all times in one position or the other by solenoid force or by return spring force.

Single solenoid valves are, therefore, preferred for spool stability but they are more difficult to adapt to pushbutton control. A holding relay must be added to the electric circuit. It will accept a momentary signal and will lock in electrically to keep current on the valve solenoid coil. A "holding" relay is simply a standard relay wired through a set of its own contacts to keep itself (and the valve coil) energized. See Page 27 for more information.

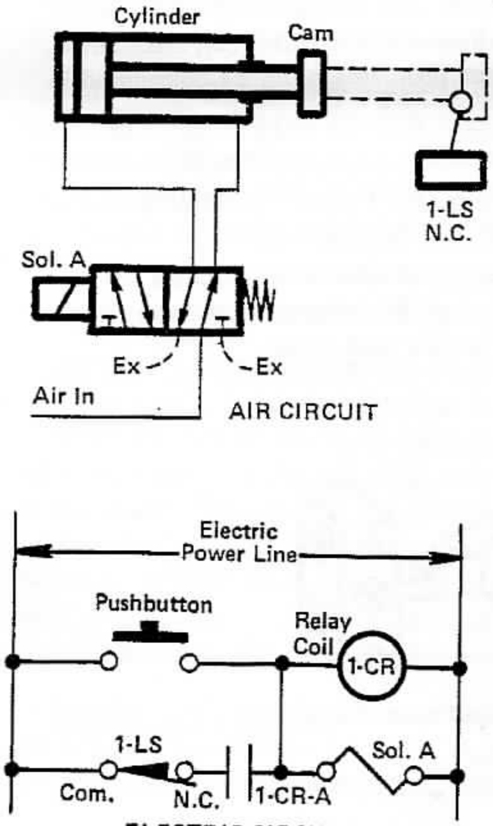


FIGURE 6-2. A holding relay circuit.

Air Circuit. Example of an air cylinder controlled with a single solenoid air valve. Cycle start will be from a momentary pushbutton. The cylinder will make a forward stroke, actuate limit Switch 1-LS, retract automatically and stop. Design an electric circuit to work from a momentary pushbutton and provide an autmatic cycle.

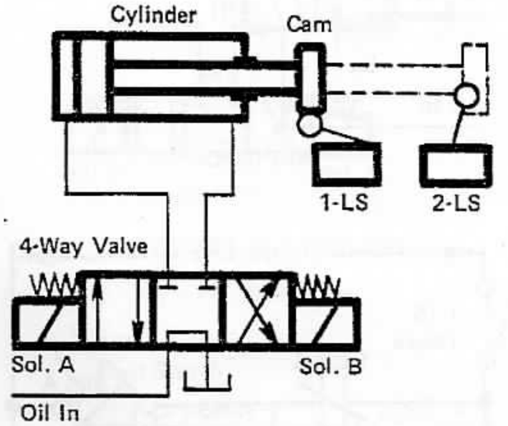
Electric Circuit. A momentary signal from an operator's pushbutton would energize the solenoid valve and start the cylinder forward, but if the button were released, the cylinder would immediately retract without completing its full stroke. A holding relay, 1-CR, must be added to take over for the operator and keep the cylinder moving after the button has been released.

Electrical action is as follows: When the button is pressed, Solenoid A and relay Coil 1-CR become energized. After closing, the relay keeps itself and the valve solenoid energized by electrically locking in through 1-CR-A and 1-LS contacts. The solenoid valve shifts and starts the cylinder forward. When Switch 1-LS is actuated, its contacts open and unlock the relay coil. Solenoid A then becomes de-energized, its spool is released and returns to its normal state by spring force, and the cylinder retracts.

DESIGN PROBLEM No. 2

How to use the momentary signal from a starting pushbutton to operate a hydraulic cylinder controlled by a 3-position spring centered 4-way valve.

Most hydraulic cylinders are controlled with double solenoid, 4-way valves having 3-position spring centered spools. These valves present a problem when trying to control them from momentary pushbuttons because the spool springs back to center neutral when the button is released. Obviously, holding relays must be added to the electric circuit to maintain current on a valve solenoid after the pushbutton has been released. Control circuit design is more difficult than for an air cylinder on a similar application, (a), because holding relays may be necessary on both forward and reverse strokes, and (b), the oil supply must be unloaded to tank at the end of the cycle.

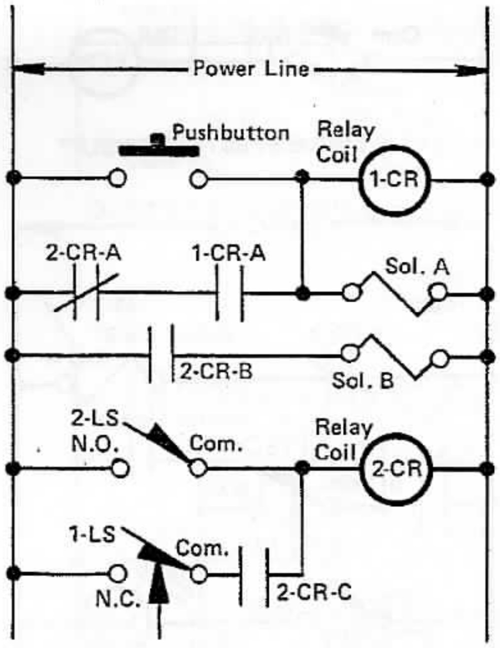


HYDRAULIC CIRCUIT

Hydraulic Circuit. The problem is to initiate a cylinder action with a "Cycle Start" momentary pushbutton, and to cause the cylinder to go through one complete cycle automatically, forward and reverse. At the end of the cycle, with the cylinder stopped, the oil supply must be in an unloaded condition. A tandem center 4-way valve is chosen for this illustration. When its spool is centered, the cylinder ports are oil-locked and the oil supply unloaded to tank.

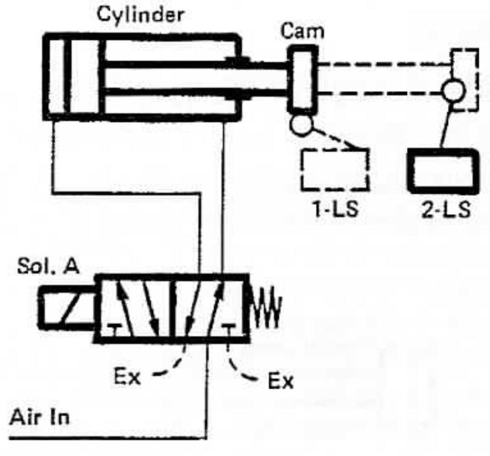
Electric Circuit. Two limit switches must be used. Switch 2-LS is placed at the forward end of the stroke to reverse the cylinder. Switch 1-LS senses the completion of a cycle and unloads the oil supply by de-energizing both solenoids of the 4-way valve. Wiring to 1-LS is to its COM and N.C. terminals. A cam on the machine keeps this switch actuated while the cylinder is retracted.

When the pushbutton is pressed, Solenoid A and the relay coil, 1-CR, become energized. The relay locks in through 1-CR-A and 2-CR-A contacts and maintains current on Solenoid A during the forward stroke, even though the button is released. When 2-LS is actuated, Relay 2-CR becomes energized and locks in through 2-CR-C and 1-LS. Solenoid B becomes energized through 2-CR-B while Solenoid A becomes de-energized when 2-CR-A opens. Relay 1-CR drops out at this time. The cylinder retracts and actuates 1-LS. This releases 2-CR relay. Both valve solenoids are now de-energized, the valve spool centers by spring action, and the oil supply is unloaded to tank through the valve spool.

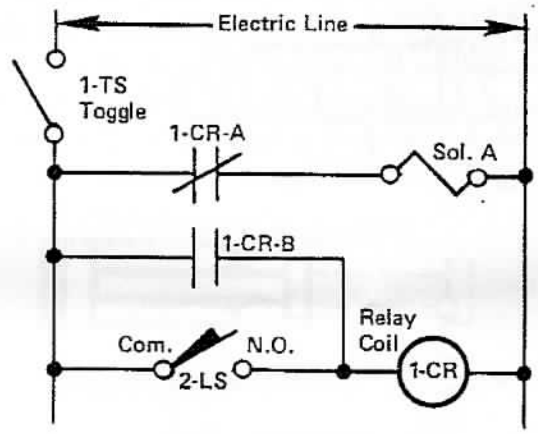


ELECTRIC CIRCUIT

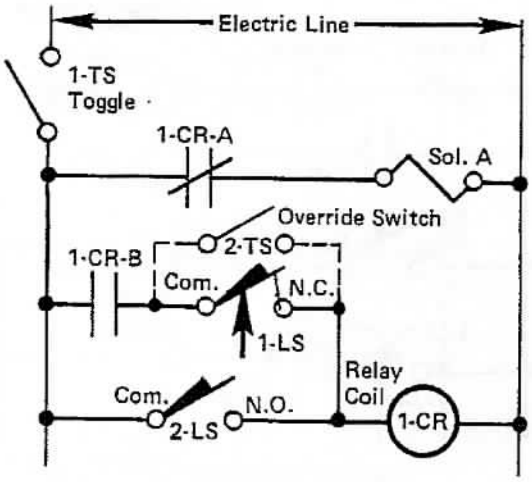
FIGURE 6-3. Holding relays enable a hydraulic cylinder to be operated from a 3-position, spring centered, tandem center valve.



AIR CIRCUIT



ONE-CYCLE ELECTRIC CIRCUIT



CONTINUOUS RECIPROCATION

FIGURE 6-4. Air cylinder reciprocation started from a maintained signal.

DESIGN PROBLEM No. 3

How to use the maintained switching signal from a toggle switch to cause an air cylinder to go through one automatic cycle, forward and back, and stop.

Air Circuit. The starting signal can come from the closure of a toggle or rotary selector switch, or may come from the output of another machine or from a programmer. The cylinder must make only one cycle and then stop. For a 1-cycle action such as this, limit Switch 1-LS is not required.

Electric Circuit. On closure of toggle Switch 1-TS, valve Solenoid A becomes energized, shifts, and the cylinder makes its forward stroke. When limit Switch 2-LS is actuated, Relay 1-CR coil becomes energized. One set of relay contacts, 1-CR-B, locks the relay in electrically. The other set, 1-CR-A, de-energizes Solenoid A. The cylinder retracts and stalls at home position. Toggle Switch 1-TS must first be opened, then closed, to start another cycle. If the starting signal comes from a programmer, it must be interrupted, then re-applied, to start another cycle.

DESIGN PROBLEM No. 4

How to use a maintained signal from a toggle switch to start an air cylinder into continuous reciprocation.

Air Circuit. Use the same circuit shown at top of this page, adding limit Switch 1-LS.

Electric Circuit. The action is much the same as described above for 1-cycle reciprocation except that when the cylinder returns to home position, Switch 1-LS breaks the holding circuit to Relay 1-CR, starting the cylinder forward again.

To stop the cylinder, toggle Switch 1-TS must be opened, or the input signal, if from a programmer, must be interrupted. The cylinder will immediately retract to home position from wherever it may be in its stroke at the time.

An override toggle Switch 2-TS can be added in parallel with limit Switch 1-LS to give a choice of 1-cycle or continuous reciprocation. With override Switch 2-TS closed, the cylinder will stop after completing one cycle.

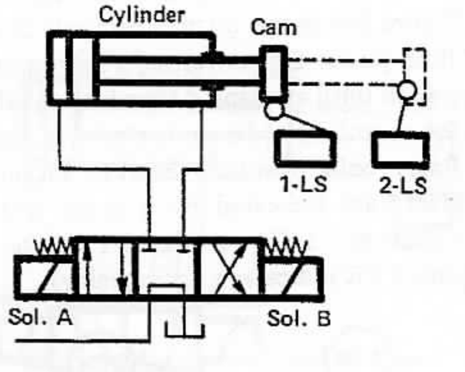
DESIGN PROBLEM No. 5

How to use a maintained starting signal, as from a toggle switch, to cause a hydraulic cylinder to go through one reciprocation cycle and stop with the pump unloaded.

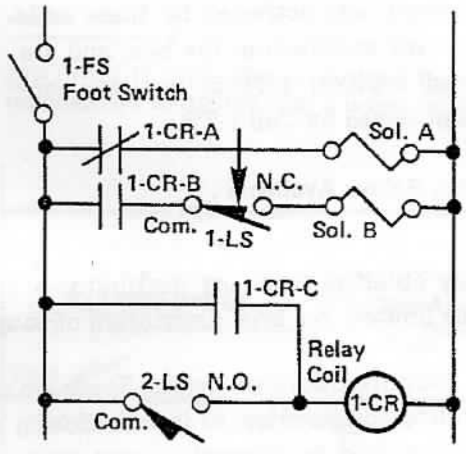
A typical application is on a hydraulic press operated with a foot switch. The operator presses and remains standing on the switch while the press goes through one cycle and stops. To start the next cycle he must release the foot switch and press it again. He can instantly stop the press at any time in case of emergency by raising his foot from the switch.

Hydraulic Circuit. Operation is with a 3-position, tandem center valve. A limit switch is placed at each end of the cylinder or press travel.

One-Cycle Cylinder Action. When foot Switch 1-FS (or a hand switch) is closed, valve Solenoid A becomes energized and the cylinder advances until it actuates Switch 2-LS. Relay 1-CR becomes energized. One set of relay contacts locks the relay closed, the other two de-energize Solenoid A and energize Solenoid B, causing the cylinder to retract. At home position 1-LS is actuated, de-energizing Solenoid B, stopping the cylinder and unloading the oil supply. The relay remains energized until the operator removes his foot from the switch. A new cycle starts when he again presses the switch.



HYDRAULIC CIRCUIT



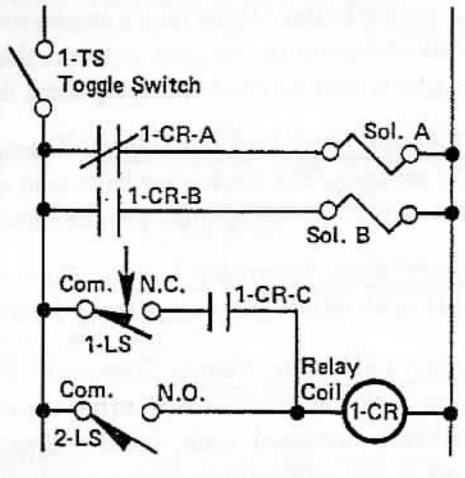
ONE-CYCLE ELECTRIC CIRCUIT

DESIGN PROBLEM No. 6

How to use a toggle switch to start a hydraulic cylinder into continuous reciprocation. When the toggle switch is opened, the oil supply must unload to tank.

Hydraulic Circuit. The same hydraulic circuit shown above is also used for continuous reciprocation.

Electric Circuit. The action for continuous reciprocation is similar to that described above except that when the cylinder retracts to home position and actuates 1-LS, the holding circuit to Relay 1-CR is broken. When the relay contacts change, Solenoid A is again energized for another cycle. If 1-TS is opened during progress of the cycle the solenoid valve spool centers, unloading the oil supply and stopping the cylinder immediately at that point in its stroke.



CONTINUOUS RECIPROCATION

FIGURE 6-5. Hydraulic cylinder reciprocation started from a maintained signal.

THE USE OF TIME DELAY RELAYS

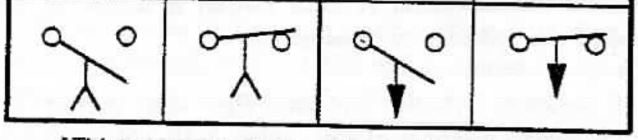
Relays with delayed contact action are shown in this chapter: on Page 116 for controlling a cylinder from a maintained starting signal; Page 125 for cylinder dwell; Page 139 for oil decompression; Page 144 for two-hand safety circuits; and Page 159 for starting a string of electric motors one at a time.

Figure 6-6 shows graphic symbols of timing relays for use on diagrams. The model most often used in fluid power for converting a maintained signal into a short pulse is one having N.C. contacts that do not open until an elepsed time interval after the coil has been energized. It is indicated with an asterisk in the chart below. Its use is shown in Design Problem No. 7 on the next page.

Relay coils operating delayed action contacts are indicated by a circle, and are marked 1-TR, 2-TR, 3-TR, etc. (Symbol TR indicates a timing relay).

Contact sets activated by these coils are drawn as shown in the box, and are marked 1-TR-A, 1-TR-B, etc., for contacts operated by Coil 1-TR.

If Contact Action is Retarded After Coil is Energized.		If Contact Action is Retarded After Coil is De-energized.	
N.O.	N.C.*	N.O.	N.C.



*This type most often used in starting cylinders.

FIGURE 6-6. This table shows the correct way to draw time delay relay contacts on diagrams.

Timing Relays Available . . .

There is a wide variety of electrical timing devices available from many sources. Information can be readily obtained from any distributor of industrial electrical components. Our discussion in this book will be limited to a brief description of some of the types available.

1. Industrial Control Relays. These are available in several NEMA sizes with delayed action contacts or with a combination of instant closing and delayed action contacts. In general these are the same structures used in magnetic motor starters but without thermal overload protective devices. Delay action is usually produced by a small pneumatic dashpot with adjustable orifice which can be set from 0 to 2 or 3 minutes. These relays can be ordered either with delayed action on energization of the coil or on de-energization, but not both on the same relay. These relays are reliable and are recommended as one of the best ways of obtaining short delays in electric control circuits.

2. Silicone Fluid Dashpot Relays. These are available from several manufacturers with delays up to 5 to 10 seconds. The models we have seen are for light duty and should be used to energize a relay. All inrush solenoid current should then be handled through a contactor operated from this relay.

3. Solid State Electronic Timers. These timers feature almost unlimited life, great accuracy, and are available with adjustable delays from fractions of a second to minutes, hours, days, weeks, or months.

4. Thermal Delay Relays. Relatively inexpensive and with good relieability, although repetitive accuracy is not as good as with other types. For better accuracy, the element must be allowed to cool before being energized again. Cooling time could be approximately the same as heating time. They are available in non-adjustable delays up to about 3 minutes.

5. Motor-Driven Re-Set Timers. Very accurate but with probably a shorter life than industrial timing relays or solid state timers. Available with adjustable delays up to 5 minutes, sometimes longer.

DESIGN PROBLEM No. 7

How to use a maintained signal from a toggle switch to give an impulse for operation of air cylinders controlled with 2-position, double solenoid valves. Delay relay method is illustrated in this problem.

Air Circuit. An electric circuit is to be designed for 1-cycle reciprocation of an air cylinder. When the cylinder is started by an electric signal, it makes a forward stroke, actuates limit Switch 1-LS, automatically retracts and stops.

The starting signal, in this case, is to be obtained from a maintained source such as a toggle switch or a switch on another machine or process. The control circuit must be designed so no matter how long the starting signal is maintained it will not interfere with cycle action and stopping at the proper time.

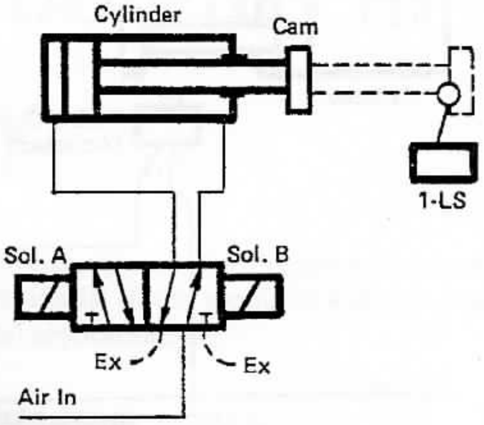
A double solenoid 4-way valve with two positions was selected for directional control of the cylinder.

Electrical Circuit A. This illustrates the nature of the problem to be solved when attempting to operate a 2-position solenoid valve from a toggle switch start.

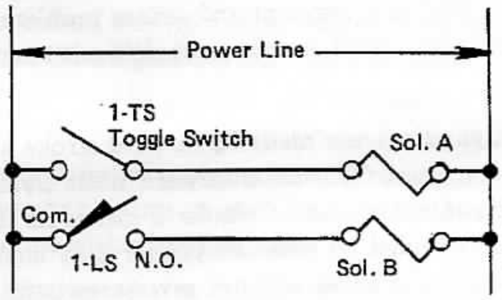
When toggle Switch 1-TS is closed, Solenoid A becomes energized, the valve spool shifts, and the cylinder starts forward. When it actuates 1-LS, Solenoid B becomes energized but the valve cannot reverse because current is still held on Solenoid A, and this circuit must be broken before the valve can be reversed with Solenoid B. One way to solve this problem is shown in Electrical Circuit B. Note: Energizing both coils at the same time, on some valves, may burn out one coil.

Electrical Circuit B. A relay with delayed action contacts or a timer can be added to Circuit A. Now, when the starting toggle switch is closed, Solenoid A is energized through N.C. delayed action contacts, 1-TR-A. After a delay of about 1 second, these contacts open, removing current from Solenoid A. However, the valve spool stays in its shifted position. At the end of the forward stroke, Switch 1-LS is actuated. This energizes Solenoid B, causing the cylinder to retract and stall at home position.

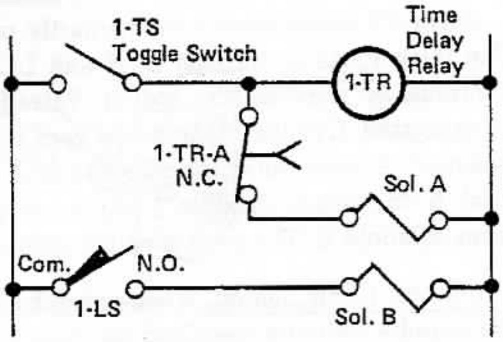
Delay Relay 1-TR converts the steady signal from the toggle switch into a short pulse. After one cycle the cylinder stops even though the toggle is still closed. To start another cycle the toggle must be opened then re-closed, allowing the relay to re-set.



AIR CIRCUIT. This cylinder is to have 1-cycle reciprocation controlled with a toggle switch.



Electrical Circuit A. The basic circuit shown here is unworkable without the addition of a time delay relay as shown in the circuit below.



Electrical Circuit B. A relay with delayed action contacts provides one solution for the problem of the previous circuit.

FIGURE 6-7. Delay Relay Circuitry.

DESIGN PROBLEM No. 8

How to release a sustained signal, developed during progress of a cycle and usually caused by a cylinder actuating a limit switch then continuing to stand on it.

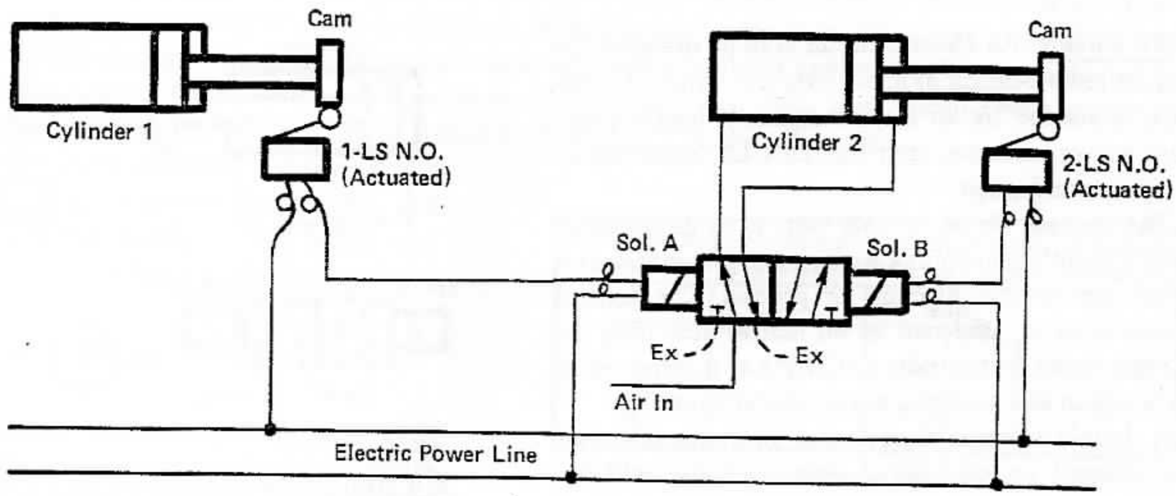


FIGURE 6-8. Illustration of the problem.

This is a frequent and serious problem encountered during the design of an electrical control circuit and one which is sometimes difficult to solve. First an explanation of the problem:

Figure 6-8. This is only a partial circuit to show the components usually involved in the problem. Cylinder 1 has made its forward stroke and actuated limit Switch 1-LS. This energizes valve Solenoid A to start Cylinder 2 forward while Cylinder 1 continues to hold at full extension and keeps 1-LS in its actuated state. Cylinder 2 makes its forward stroke and actuates 2-LS. The signal from this switch is intended to reverse Cylinder 2 by energizing Solenoid B. But with the other cylinder standing on 1-LS, the valve will not reverse and the circuit stalls. To solve this problem, some means must be found to interrupt current to Solenoid A after it is no longer needed. Several methods may be used:

Standard Limit Switches. The problem has been solved in Figure 4-6 on Page 68. A holding relay has been used to break the circuit to Solenoid A. This description refers to Figure 4-6:

When PB pushbutton is momentarily pressed, valve Solenoid A and Relay 1-CR become energized. The relay locks in through 2-LS and 1-CR-B. Cylinder 1 moves forward, actuates Switch 1-LS, and continues to stand on this switch. Valve Solenoid C becomes energized while Solenoid A continues to be energized. Cylinder 2 moves forward and actuates 2-LS. This drops out Relay 1-CR and disconnects Solenoid A while energizing Solenoid D. Cylinder 2 retracts and actuates 3-LS. This energizes Solenoid B to retract Cylinder 1. At home position, Switch 4-LS is cammed open to remove current from Solenoid B. The cycle is ended with current removed from all solenoids.

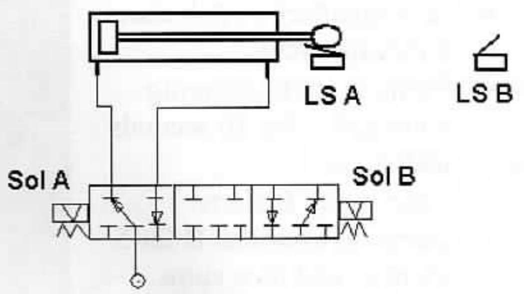
Impulse Limit Switch. When using 2-position, 4-way valves to operate air or hydraulic cylinders, the impulse switches described on Page 71 and illustrated in Figure 4-8 can be used to give a momentary impulse even though a cylinder may continue to stand on them.

Delay Relays. The steady signal produced in the above figure when Cylinder 1 stands on 1-LS can be converted to a momentary or short duration signal using a delay relay as shown in Design Problem 7, or by using a mechanical or electronic timer to disconnect Solenoid A after a brief delay.

1- TRiLOGI 6 (Educational)

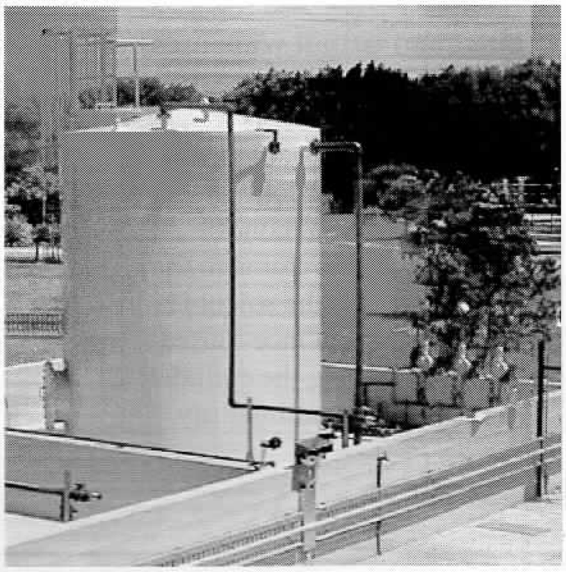
Assignments – MEM30027A

Task 1 (input and output with latch)

A pneumatic cylinder is controlled by a 3-position, spring-centred solenoid actuated directional control valve. The valve returns to the centre position is the solenoids are de-energized. Once started with a start switch, the cylinder will reciprocate continuously.	

Ladder diagram

Task 2 (Timer)



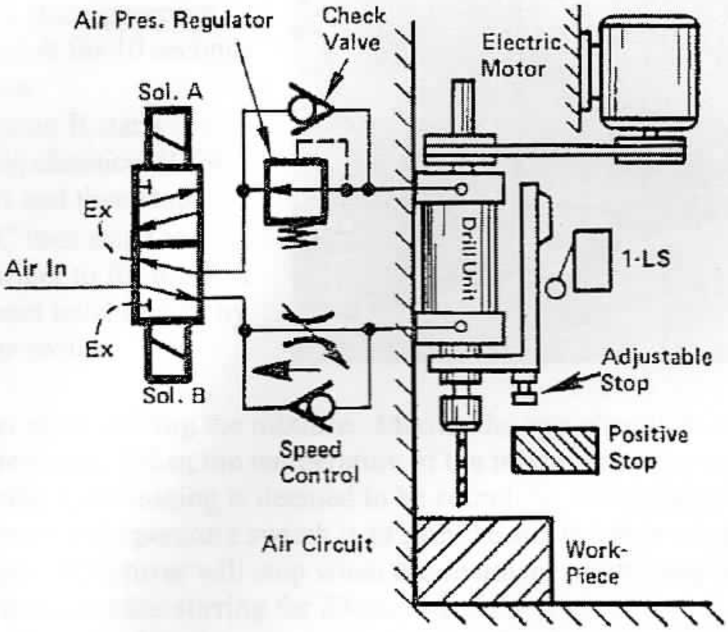
Two chemicals are to be mixed in a tank.

- A momentary switch starts a mixing cycle
- Pump A starts pumping chemical A for 10 seconds and stops.
- Then pump B starts pumping chemical B for 5 seconds and then stops.
- Pump C then starts to pump water to fill the tank to a preset level sensed by a sensor switch.
- A stirrer starts stirring the mixture. Mixing the two chemicals with stirring generates heat. When the temperature of the mixture rises to a preset temperature, the mixing is deemed to be complete. A temperature sensor in the form of a temperature switch is to stop the stirrer when mixing is complete. The stirrer will stop when the chemical reaches the preset temperature or after stirring for 20 seconds.
- A solenoid valve is to be open to let the completed mixture to run out of the mixing tank and fill into a delivery drum.

Ladder diagram

Task 3 (Timer)

Dwelling time in the pneumatic circuit. Each time the button is pressed, cylinder advances to a positive stop, dwells and then retracts. Make up a dwell time for this task.

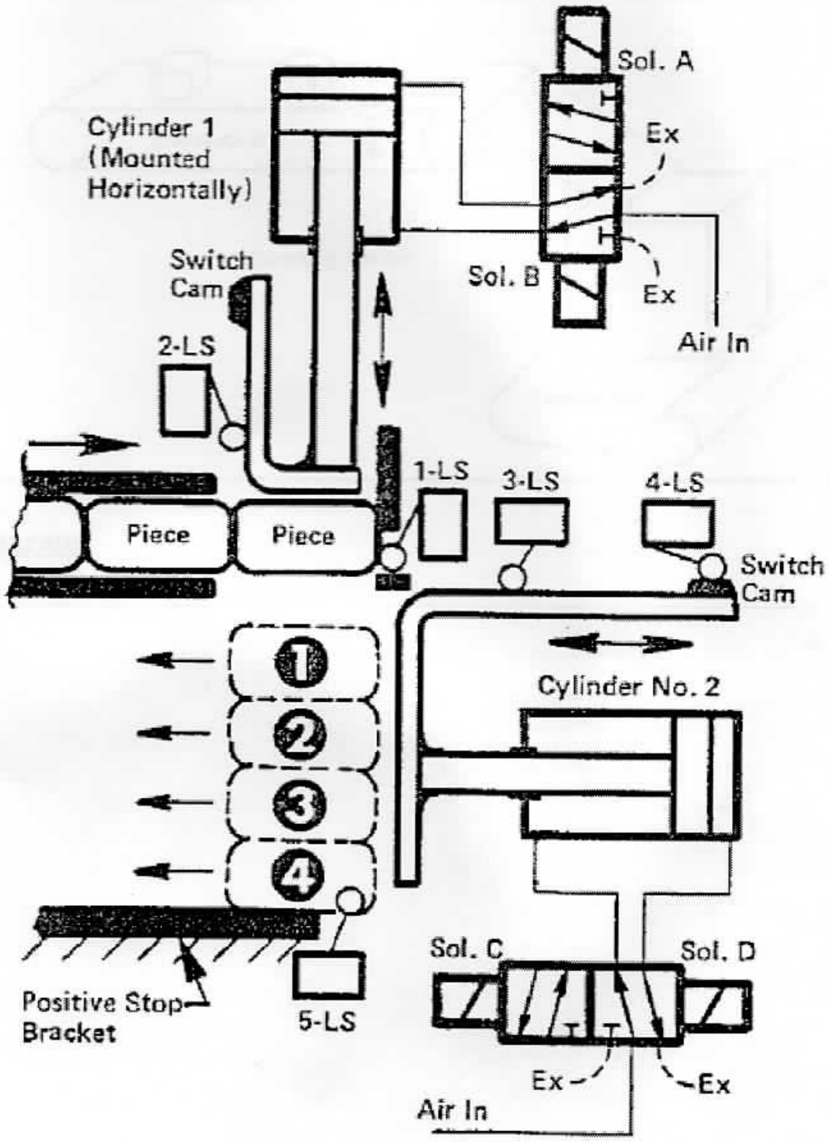


Ladder Diagram

Task 4 (Counter)

This is an arrangement of two cylinders working in a horizontal plane.
It is set up to accept a single line of pieces or parts usually delivered form a conveyor, and to count them out in groups. It works automatically, without an operator, and will accept pieces coming at spaced intervals or with no space between.

When an entering piec3e moves in front of cylinder 1, this cylinder makes a forward and return stroke, pushing the piece to Position 1. The action continues to repeat, stacking piece on piece, until the first piece to enter has reached Position 4, cylinder 2 then makes a forward and return stroke to push the stack out of the way.

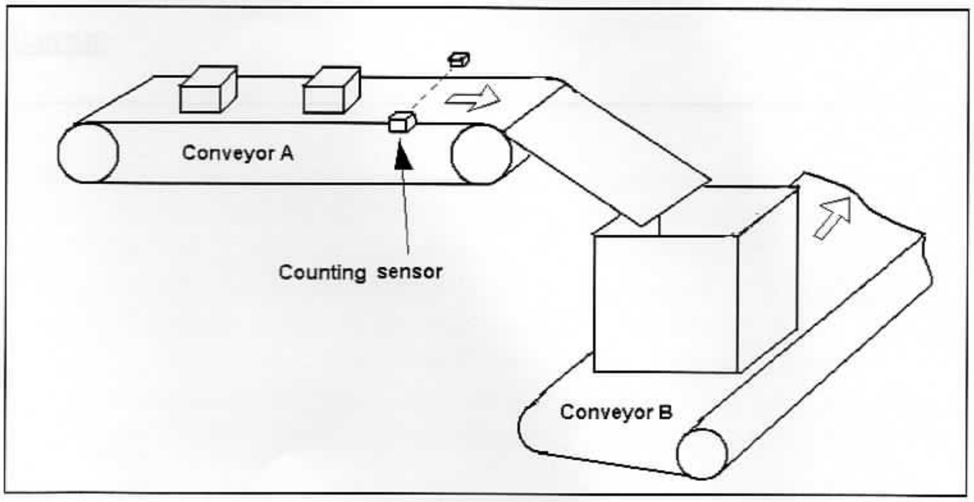


Ladder Diagram

Task 5 (timer and counter)

Conveyor A moves parts to packing. An infrared interrupting sensor sensing the movement of a part. The parts drop into a packing box at the end of conveyor A.

- The box rests on conveyor B and it can hold 10 parts.
- A counter keeps counting of the number of parts dropped into the box.
- It takes 2 seconds for a part to move from the counting device on conveyor A to dropping into the box.
- Once 10 parts have dropped into the packing box, conveyor A is stopped and conveyor B starts to move
- 5 seconds is required to move away the filled box and put in another empty box on conveyor B.
- Conveyor A starts to move again after an empty box is ready.



Ladder diagram